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WAVE-LIKE PROGRESS OF AN EPEIROGENIC UPLIFT.[1]

To the ancient Greeks the word *epeiros*, specially applied to the land lying next north, signified also, in general, any mainland or continental area, as contrasted with islands or their own peninsular country. From this word Gilbert has recently supplied to our science the terms *epeirogeny* and *epeirogenic*, to designate the broad movements of uplift and subsidence which affect the whole or large parts of continents and of the oceanic basins.[2] Previously the correlative terms *orogeny* and *orogenic* had come into use, denoting the process of formation of mountain ranges by folds, faults, upthrusts and overthrusts, affecting comparatively narrow belts and lifting them in great ridges, while the epeirogenic movements of the earth's crust produce and maintain the continental plateaus and the broad depressions which are covered by the sea.

During the closing part of the Tertiary era and the present Quaternary or Psychozoic era, both epeirogenic and orogenic changes have been in progress on many portions of the earth, and on a scale of grandeur probably never before surpassed. Where these movements have raised continental regions or mountain districts to much greater altitudes than they now retain, if they were situated within the range of prevailing air currents abundantly laden with moisture and were at latitudes so far from the equator that the precipitation was chiefly snow throughout the year, they became for a time enveloped by ice-sheets, which have left the surface strewn with glacial and modified drift. Fjords, and now submarine continuations of river

[1] Presented before the World's Congress on Geology, auxiliary with the Columbian Exposition, Chicago, August 25, 1893. This paper is an attempt to answer, by a definite example, a portion of the inquiries in an editorial of the JOURNAL OF GEOLOGY, Vol. 1, page 298, April–May, 1893.

[2] "Lake Bonneville," Monograph I., U. S. Geological Survey, 1890, p. 340.

valleys, attest for the northern two-thirds of North America such late Tertiary and Quaternary epeirogenic uplift at least 2,000 to 3,000 feet above the present height of this continent; for the British Isles, Scandinavia, and probably the greater part of Europe, an uplift 1,000 to 4,000 feet higher than now; and for the western side of Africa within a few degrees both north and south of the equator, 3,000 to 6,000 feet.[1] Attending the subsidence of these areas, greatly increased altitudes have been given by folding, rifts, and upthrusts, to large portions of the highest mountain systems of the world, as the Alp-Himalayan and Andes-Cordilleran belts.[2] The most recent of all mountains, excepting volcanic cones, probably is the lofty St. Elias range, according to Russell's observations; and the belt in which this is a part has an extent of two-thirds of the circumference of the globe, from Cape Horn to Alaska, the Aleutian Islands, Kamtchatka, the Kuriles, Japan, and the Philippine islands, intersecting the eastern part of the Alp-Himalayan belt near Krakatoa, in the earth's most volcanic and seismic district.

The drift-bearing areas in North America, in Europe, and in Patagonia, which at the end of their epoch of gradual elevation and fjord erosion had become deeply covered by land-ice, sank under its weight until when the ice melted away they mainly stood somewhat lower than now. The shores of the sea at that time in the St. Lawrence and Ottawa valleys, in the basin of lake Champlain, and about Hudson bay, have been again uplifted,

[1] J. W. SPENCER, Bulletin, Geol. Soc. Am., Vol. 1., 1890, pp. 65–70 (also in the Geol. Magazine, III., Vol. 7, 1890, pp. 208–212). J. D. DANA, Am. Jour. Sci., III., Vol. 40, pp. 425–437, Dec., 1890, with an excellent map of the Hudson submarine valley and fjord. G. DAVIDSON, Bulletin of the California Academy of Sciences, Vol. 2, 1887, pp. 265–268. T. F. JAMIESON, Geol. Mag., III., Vol. 8, pp. 387–392, Sept., 1891. J. Y. BUCHANAN, Scottish Geographical Magazine, Vol. 3, 1887, pp. 217–238.

[2] H. B. MEDLICOTT and W. T. BLANFORD, Manual of the Geology of India, Calcutta, 1879, Part I., pp. lvi, 372; Part II., pp. 569–571, 667–669, 672–681. J. LE CONTE, Am. Jour. Sci., III., Vol. 32, pp. 167–181, Sept. 1886; Bulletin, Geol. Soc. Am., Vol. 2, 1891, pp. 323–330; Elements of Geology, third edition, 1891, pp. 250–266, 589. J. S. DILLER, Eighth An. Rep., U. S. Geol. Survey, for 1886–87, pp. 426–432; JOURNAL OF GEOLOGY, Vol. 2, pp. 32–54, Jan.–Feb., 1894. I. C. RUSSELL, National Geographic Magazine, Vol. 3, 1891, pp. 172, 173. W. UPHAM, Appalachia, Vol. 6, 1891, pp. 191–207 (also in Pop. Sci. Monthly, Vol. 39, pp. 665–678, Sept. 1891).

but only to a comparatively small amount, from 200 to 500 or 600 feet, after the departure of the ice-sheet. In Scandinavia, according to the investigations of Baron de Geer, the postglacial uplift has varied from a minimum of 100 feet or less at the southern extremity of Sweden, to a maximum exceeding 1,000 feet in the central part of the peninsula.[1] Likewise in South America, along a distance of 1,200 miles, from the Rio Plata to Tierra del Fuego, the land has been elevated since its glaciation, the general extent of this movement in Patagonia, as observed by Darwin, being between 300 and 400 feet.[2]

The special case of an epeirogenic movement progressing like a wave, which it is the purpose of this paper to consider, is this latest, moderate uplift of North America, and especially of its central belt comprised in the Mississippi and Nelson river basins, from its depression at the close of the Glacial period. While the ice-sheet was retreating, this great area was rising as fast as its burden was removed. Close upon the wasting ice-border there followed a wave of permanent uplift of the land on which it had lain. First the loess district along the Mississippi and the upper part of this basin were elevated; next, the southern half of the area of the glacial lake Agassiz; later, its northern half; and last of all, the country enclosing Hudson bay, with which also was probably associated, as very late in its uplift, the region of the great Laurentian lakes, including lake Champlain, and of the Ottawa and the St. Lawrence. From south to north and northeast the wave of elevation advanced, and, according to Dr. Robert Bell, the rise of the land has not yet ceased about James and Hudson bays, where, in the central part of the glaciated region, we must suppose that the ice-sheet had its greatest thickness and was latest represented by lingering remnants. Having thus outlined our theme, let us return and look more

[1] Bulletin, Geol. Soc. Am., Vol. 3, 1891, pp. 65–68, with map of the late glacial marine area in southern Sweden; Proceedings of the Boston Society of Natural History, Vol. 25, 1892, pp. 456–461 (also in the Am. Geologist, Vol. 11, pp. 23–29, Jan., 1893).

[2] "Voyage of H.M.S. Beagle," chapter viii.

fully at the evidence of this progressive earth movement in the chronologic and geographic order of its successive portions.

Between the chief time of deposition of the Mississippi loess and the formation of the prominent moraines east of the Wisconsin driftless area, there intervened an uplift of the upper Mississippi region to a vertical extent estimated by Chamberlin and Salisbury as probably 800 to 1,000 feet.[1] On the western portion of the driftless area and southward to the Gulf of Mexico, the loess had been spread by very slowly flowing river floods, and partly in temporary lakes, due to the greater depression of the basin toward the north, while in the opposite direction the subsidence was insufficient to carry the low southern part of the valley beneath the sea level. The ensuing uplift probably scarcely increased the altitude of that southern area about the mouth of the Mississippi, but thence it extended northward as a differential epeirogenic movement, raising the depressed country of the central and northern portions of this great river basin several hundred feet. As a result of the changed slope, in the former place of the quiet water whose sediment was the loess, strong currents, bearing sand and gravel, flowed down the valleys from the ice-front when it amassed the moraines mentioned in Wisconsin. The duration thus represented has been supposed to comprise a long interglacial epoch, but the observations on which this belief rests seem to me to admit a different interpretation.

On the drift border, in some parts of southern Illinois and Indiana, the loess was deposited, according to Salisbury, immediately after the till which immediately underlies it, and was in part contemporaneous with the till. As soon as the ice-sheet retired from the positions where this relationship exists, the glacial drift was covered by this finer silt of the modified drift supplied by streams that flowed from the melting and retreating ice.[2] In the northeastern part of Iowa, McGee similarly finds the

[1] "Preliminary Paper on the Driftless Area of the Upper Mississippi Valley," Seventh An. Rep., U. S. Geol. Survey, for 1884–85, pp. 199–322.

[2] "The Geology of Crowley's Ridge" (1891), Geol. Survey of Arkansas, An. Rep. for 1889, Vol. 2, pp. 228, 229.

loess to have been deposited while the ice-sheet that spread the upper portion of the early till was melting away. The very remarkable paha of that district, which are eskers of loess, were accumulated while the waning ice-sheet walled them in at each side.[1] That the later part of the loess deposition was contemporaneous with the formation of the Altamont moraine, belonging to the later drift and marking its limits, I ascertained in northwestern Iowa, where this moraine along a distance of seventy-five miles, from Guthrie county northwestward to Storm Lake, is bordered on its west side by an expanse of loess as high as the crests of the morainic hills, while its elevation above the expanse of till eastward is from fifty to seventy-five feet. During the time of deposition of this part of the loess the ice-sheet reached to the Altamont moraine and was a barrier preventing the waters by which the loess was brought from flowing over the lower area of till that reaches thence east to the Des Moines river.[2] On three widely separated tracts the loess, as elsewhere the coarser portions of the modified drift forming sand and gravel plains, was in progress of deposition upon successive areas as fast as the ice-sheet supplying these stratified drift beds receded. Immediately after the land was bared by the retreat of the ice, and even while the ice itself occupied the adjoining land, the loess was being laid down, contemporaneous successively with the early till on the southern border of the drift, with the till of intermediate age in northeastern Iowa, and with the later till enclosed by the Altamont moraine. The loess deposition I believe to have been mainly continuous, accompanying the gradual and widely extended but wavering departure of the ice-sheet from its farthest boundary to this outermost of the conspicuous morainic belts.[3]

[1] U. S. Geol. Survey, Eleventh An. Rep. for 1889-90, pp. 435-471.

[2] Geol. and Nat. Hist. Survey of Minnesota, Ninth An. Rep. for 1880, pp. 307-314, 338.

[3] The interpretation of the loess and glacial history of the Mississippi basin which I here present differs widely, it must be acknowledged, from the opinions of Professors Chamberlin and Salisbury, and Messrs. McGee and Leverett, to whom we owe so much of the critical investigation of this area. These observers have been led by their

While the ice was retreating and supplying the loess, the land thus uncovered and relieved from the ice weight had been gradually rising, until it had attained approximately its present height in Wisconsin, Iowa, and southern Minnesota, before the formation of the moraines. This altitude has endured, excepting minor

studies to conclude that between the deposition of the early till in southeastern Illinois, with its accompanying loess, and that of the till and attendant paha or eskers of loess in northeastern Iowa, there intervened a very long and diversified history of glacial recessions and re-advances, including at least one prolonged interglacial epoch. A summary of these views in relation to the glacial succession in Ohio is well stated by Mr. Frank Leverett in this JOURNAL OF GEOLOGY, Vol. 1, pages 129-146, Feb.-March, 1893. From my early study, "Modified Drift in New Hampshire" (Geol. of N. H., Vol. 3., 1878, chapter i., pp. 3-176, with maps and sections), and from my later work on the Glacial Lake Agassiz, I am strongly impressed with the conviction that the deposition and ensuing erosion of the drift, both till and stratified beds, as the loess, went forward very rapidly. What these authors have ascribed to interglacial epochs, one or more of them of great length, seems to me to be more probably referable to geologically very short stages of fluctuation of the mainly waning ice-sheet.

Professor Salisbury, in the report cited, shows that there were two successive deposits of till, and a corresponding division of the loess, on and near to the boundaries of the drift; these seem to me probably due to two closely consecutive stages of ice advance, instead of the long time interval which he thinks to be indicated. Again, in the report on northeastern Iowa, to which reference was given, Mr. McGee clearly shows, chiefly by the forest bed intercalated between two sheets of till, that likewise there the ice advanced twice, with a considerable intervening time, which he supposes to have been far longer than the Postglacial epoch. To my mind, however, the forest-covered borders of the Malaspina glacier or ice-sheet in Alaska leave no doubt that forest beds enclosed in till may be due to oscillations of the ice-front within distances of no more than a few miles or even less than one mile, and that they may have required no longer interval than a few tens of years or at most a century, sufficient for the forest growth, between the times of ice retreat and re-advance.

When the depression of the ice-loaded land brought it down to so low altitude that the borders of the ice-sheet began to be melted more rapidly than they received increase by snowfall and onflow from the thicker central portion of the ice, a general recession of the glacial margin ensued. On the southern part of the drift in the Mississippi basin no continuous moraines were accumulated, and I attribute their absence principally to the attenuated condition of the ice there and its lack of a steep border. During the glacial retreat, wherever the wavering climate caused the mainly waning ice-border to remain nearly stationary during several years the vigorous outflow of the ice to its then steep frontal slope brought much drift, forming belts of irregular morainic hills and ridges, and leaving many hollows which enclose lakes. The fluctuations of the general glacial retreat seem to me to have been due principally to variations of snowfall, some long terms of years having much snow and prevailingly cool temperature, therefore allowing considerable glacial re-advance, while for the greater part other series of years favored rapid melting and retreat.

and unimportant oscillations, from that time until now. The beginning or earliest known stage of the progressive elevatory wave probably thus raised the northern half of the Mississippi basin to a variable amount ranging from 100 feet or less to 500 feet or more. It was practically completed, for this area, previous to the accumulation of the outer and earlier moraines in the series of many which mark pauses in the further recession of the ice-sheet. Thenceforward the glacial melting appears to have been more rapid than before, giving to the ice steeper frontal gradients whereby its drift was amassed more commonly in hills, ridges, and lake-enclosing hollows, and especially in the very irregularly knolly and hilly moraine belts.

The rapidity of the glacial recession and of this ensuing epeirogenic uplift in its wave-like advance upon the area of the glacial Lake Agassiz, extending nearly 700 miles from south to north in the basin of the Red river and of Lake Winnipeg, surpasses all previous knowledge in what it reveals concerning the mobility of the earth's crust. The postglacial duration of Lake Michigan and its companion great lakes of the St. Lawrence has been shown, by numerous independent but well agreeing observations and estimates, to be no longer than 6,000 to 10,000 years. Now the amount of wave erosion on the shores of Lake Michigan and the resulting accumulation of beach sand, heaped into dunes upon large areas about the south end of the lake, must exceed, by a ratio of 10 : 1 or 20 : 1, the corresponding wave action in its total amount at all the successive levels held by Lake Agassiz during its history, which accordingly must be comprised within some such time as 1,000 years or perhaps less.[1] During this geologically very short time, the ice was melted away upon the distance of 700 to 1,000 miles from the middle of the west side of Minnesota to James and Hudson bays, and the Lake Agassiz basin was differentially uplifted mostly 300 to 500 feet, to the height which it has ever since retained without appreciable later change. To understand the wave-like devel-

[1] Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, Vol. 4, for 1888-89, pp. 50, 51 E.

opment of this uplift, it will be needful to consider it first for the southern half and afterward for the northern half of the glacial lake area.

About thirty successive levels of Lake Agassiz have been recognized by its beaches. A considerable number were due to the gradual erosion and lowering of the outlets, and to their changes of place and direction, first toward the south and later toward the northeast; but probably more than half of this whole series of lake levels are distinctly exhibited only upon the central and northern portions of the lacustrine area, being due chiefly to its differential uplift increasing from south to north, and in a small degree to the decrease in the gravitative attraction of the waning ice-sheet. The five well defined beaches near the south end of this ancient lake, named in descending order the Herman, Norcross, Tintah, Campbell, and McCauleyville beaches, formed at the successive levels of southward outflow as the channel was deepened, are each found to be represented, when they are followed northward, by two, three, or more, so that near the international boundary and in Manitoba, they become subdivided into no less than seventeen beaches, marking the stages of the subsidence of the lake and in larger proportion of the differential elevation of the land. Nearly as many other lower shore lines record the stages of the lake while it outflowed northeastward. My surveys of these shores, with exact mapping and leveling, extend more than 300 miles from the south end, to lakes Winnipeg and Manitoba and the Riding Mountain.[1]

In this southern half of the whole extent of Lake Agassiz, the shore of its highest or Herman stage, as represented at the north by the uppermost of its divided beaches, has now a northward ascent of about 35 feet in the first 75 miles north from Lake Traverse, which lies in the old channel of southward outlet, about 60 feet in the second 75 miles, and about 80 feet in the

[1] Geological and Natural History Survey of Minnesota, Eighth An. Rep., for 1879, pp. 84-87; Eleventh An. Rep., for 1882, pp. 137-153, with map; Final Report, Vol. 1 (1884), and Vol. 2 (1888). U. S. Geol. Survey, Bulletin No. 39 (1887), pp. 84, with map. Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, Vol. 4, for 1888-89, Part E, pp. 156, with maps and sections.

third distance of 74 miles to the international boundary. Its whole ascent thus in 224 miles is 175 feet, by a slope which increases from slightly less than a half of a foot per mile in its southern third to slightly more than one foot per mile in its northern third. This beach extends only a short distance farther north, having been formed when the ice-sheet lay there as the northern boundary of the lake; but the second of the Herman beaches, slightly lower and later, reaches as far northward as to the limit of my exploration, in the vicinity of Gladstone, Manitoba, and Riding Mountain, and in this distance of 308 miles, from Lake Traverse to the latitude of Gladstone, it has an ascent of 265 feet. In the four successive nearly equal parts of its extent from south to north, namely, 75 miles, again 75 miles, then 74 miles, and lastly 84 miles, it rises respectively about 35, 50, 80, and 100 feet; and almost the whole of this change of the old beach, from its horizontality at the time of formation, has been produced by the gradual uplifting of the lake basin while the ice-sheet was retreating from it.

The considerably later upper Norcross beach rises in these distances about 25, 35, 55, and 70 feet, amounting to 185 feet in the entire 308 miles. The upper Campbell beach has ascents of about 10, 15, 30, and 35 feet, or 90 feet in all; and the lowest of the three McCauleyville beaches, marking the latest stage of southward outflow of Lake Agassiz, ascends about 5, 10, 15, and 20 feet or a total of 50 feet. It is thus seen that far the greater part of the uplift of this area had been accomplished before the formation of the Campbell and McCauleyville beaches.

Beyond the limits of my leveling, portions of nearly all the shore lines of Lake Agassiz below those of the Herman series have been observed and mapped by Mr. J. B. Tyrrell, of the Canadian Geological Survey, at localities in northwestern Manitoba and eastern Saskatchewan, bordering the northern half of this lacustrine area.[1] From a careful comparison of the eleva-

[1] Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, Vol. 3, for 1887-88, Part E, pp. 16, with map; Vol. 5, for 1889-90, Part E, pp. 240, with map, sections, and illustrations from photographs.

tions of the beaches noted by Mr. Tyrrell with those determined by my surveys at the south, I am enabled to correlate very satisfactorily the two sets of shore lines. The northern continuations of the successive lake levels from the upper Norcross beach to the Niverville beaches, which mark the latest stages of the glacial lake, just before the recession of the ice-sheet from the district crossed by the Nelson river permitted it to be reduced to the Lake Winnipeg, are thus identified upon a region lying 50 to 200 miles beyond the area examined by me.

Along the base of the escarpments of Riding and Duck mountains, where Mr. Tyrrell has traced the beaches and determined their heights for a distance of fifty miles between Valley and Duck rivers, that is, between latitudes 51° 15′ and 52° N., it is found that a very important differential elevation, increasing from south to north about three feet per mile, took place after the Campbell and McCauleyville beaches were formed, since they are thus remarkably changed from their original horizontality. It is clearly shown here that the uplifting was not uniformly proportionate and regular for the whole area of Lake Agassiz. The chief movements of elevation of its southern and central part, as far to the north as Gladstone, seem not to have extended farther, at least in their full proportion. The district next to the north along an extent of 120 miles, to the north end of Duck mountain, was perhaps only so far disturbed by these movements as was necessitated to connect the rise of the country on the latitude of Gladstone with the continuing condition of maximum subsidence on the latitude of the lower part of the Saskatchewan and the north end of Lake Winnipeg. But there ensued in this district, after the date of the Campbell beach, a great differential elevation, giving to these late shore lines two or three times more northward ascent than that of the Herman beach from Lake Traverse to Gladstone; and the total change in level of the highest observed beach, probably representing the upper Norcross stage, situated at Pine river, on latitude 51° 50′ to 52° N., is approximately 400 feet, as compared with this shore line at Lake Traverse, about 420 miles distant to the south. Nearly

the whole uplift of the northern part of the basin was accomplished, however, while the ice-sheet was still a barrier of the lake, for the Niverville beach at the Grand Rapids of the Saskatchewan is only slightly higher than on the Red river, 250 miles to the south.

The southern and central part of the lake basin, reaching north to Gladstone, had been raised nearly to its present height during the first third or half of the period of the entire duration of Lake Agassiz. Then followed a time, during the second third of the lake's existence, in which the district that includes Riding and Duck mountains and extends north to the mouth of the Saskatchewan was being rapidly uplifted. But this later northward and northeastward advance of the wave of upheaval had passed beyond the Saskatchewan before Lake Agassiz was lowered to Lake Winnipeg, as is shown by the nearly level Niverville beaches. The rise of the land approximately to its present height is thus known to have followed close upon the glacial recession by which the land was relieved of the ice weight.

Latest of all, when Lake Winnipeg and the Nelson river had come into existence, the shores of Hudson and James bays were raised 300 to 500 feet from their late glacial marine submergence.[1] The remnants of the ice-sheet in that region were not melted away until much later than the glacial retreat from the northern United States and Manitoba. Moving onward with the departure of the ice, the uplifting wave of the earth's crust has raised the basin of Hudson bay 300 to 500 feet since the sea was admitted to it, and the upheaval there is not yet completed. Though doubtless slower than at first, it is still in progress, according to Dr. Bell's observations, at a probable rate of five to seven feet per century. During this last portion of the epeirogenic uplift of our continent from its Champlain depression, the whole area of Lake Agassiz, as shown by the still horizontal

[1] DR. ROBERT BELL, Geol. and Nat. Hist. Survey of Canada, Reports of Progress, for 1871-72, p. 112; for 1875-76, pp. 340; for 1877-78, pp. 7 and 32 C and 25 CC; for 1878-79, p. 21 C; for 1882-84, pp. 26-32 DD; Annual Reports, new series, Vol 1. for 1885, p. 11 DD; Vol. 2, for 1886, pp. 27, 34, and 38 G.

Niverville beaches, lay undisturbed. The loess region of the Mississippi valley, having been earliest and permanently uplifted, suffered no further change during the progressive elevation of the Lake Agassiz basin ; and that in its turn was at rest while the great area of Hudson bay has been undergoing elevation.

Having already shown that the entire duration of Lake Agassiz was about 1,000 years, we must conclude that the uplift of its area, probably to heights ranging from 100 feet to mainly about 500 feet, occurring first at the south and later at the north, took place, when in most rapid movement upward, at rates of a half a foot to one foot per year. A century, therefore, would comprise an elevation of 50 to 100 feet. The movement, however, was evidently more or less intermittent, with pauses of slower uplift or stages of rest, when the successive beach ridges were formed. Nowhere else in the records of present or past epeirogenic movements of any region have so rapid changes of level of large tracts been ascertained ; and these changes seem clearly to have occurred through a gradual deformation of the earth's crust by quiet flexure, not by faulting and earthquakes, which would break the regularity and continuity of the ascents of the beaches when traced long distances. The preglacial epeirogenic uplifts of drift-bearing areas, also apparently taking place without faulting, was probably much slower ; but their final depression beneath the ice-sheet may have been even considerably more rapid. Very sudden and great, yet not seismic, uplifts of extensive areas, as supposed by Prestwich for southern England and Wales, to account for the "head" or "rubble drift,"[1] and by Shaler for the coastal border of New England, to explain the origin and preservation of the kames,[2] seem, at least in my opinion, to be physically impossible.

The probable nature of epeirogenic movements, in their dependence on conditions of the earth's crust and interior,

[1] Quart. Jour. Geol. Soc., Vol. 48, 1892, pp. 263-343, with many sections and a map.

[2] U. S. Geol. Survey, Seventh An. Rep., for 1885-86, pp. 310, 320, 321 ; Bulletin No. 53, 1889, "The Geology of Nantucket," pp. 44, 45.

remains to be briefly noticed. Between the epochs of mountain-building by plication, the diminution of the earth's mass produces epeirogenic distortion of the crust, by the elevation of certain large areas and the depression of others; and these effects have been greatest just before relief has been given by the formation of folded mountain ranges. Two epochs have been preëminently distinguished by extensive mountain plication, one occurring at the close of the Paleozoic era, and the other progressing through the Tertiary and culminating in the Quaternary era, introducing the Ice age. During the last, besides plication and overthrust faulting of the Coast range, the St. Elias range, the Alps, and the Himalayas, a very extraordinary development of tilted mountain ranges, and outpouring of lavas on an almost unprecedented scale, have taken place in the Great Basin and the region crossed by the Snake and Columbia rivers. With the culminations of both of these great epochs of mountain-building, so widely separated by the Mesozoic and Tertiary eras, glaciation has been remarkably associated, and indeed the ice accumulation appears to have been caused by the epeirogenic and orogenic uplifts of continental plateaus and mountain ranges. These processes are well consistent with Dana's doctrine of the general permanence of the continents and oceanic basins; for upheaval of an ocean bed would not diminish but increase the earth's volume. The late glacial and postglacial uplift of North America from its Champlain depression, by the wave-like movement which has been here described, seems an effort of the earth to regain the state of isostasy, or flotation of the crust on the heavier mobile interior, which is capable of flow, whether it be solid or molten.

WARREN UPHAM.